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(54) Method and apparatus for treating fluent materials.

(57) A method for treating a continuous flow of fluent materials employs an apparatus (20, 200) comprising a generally cylindrical housing (23, 202) having an inlet (22, 204), an outlet (24, 206) and a plurality of treatment stages for successively imparting pulses of energy to the fluent materials in order to disassociate the materials on a molecular level and achieve a homogeneous, highly dispersed mixture. Each of the treatment stages includes a pair of baffle plates (50, 52, 248, 250) which are relatively rotatable and oppose the flow of fluent materials through the housing alternating zones of high pressure and cavitation. Each pair of the baffle plates include matched sets of openings (54, 56, 252, 254) therein which are periodically brought into alignment with each other as one plate rotates relative to the other, thereby allowing bursts of the fluent material to flow therethrough, from an upstream area (32, 212) of relatively high pressure into a cavitation area (84, 258). One of the baffle plates (52, 60, 248, 264) in each pair thereof is mounted on a shaft (68, 224) rotated by a motor (76) located external of the housing.

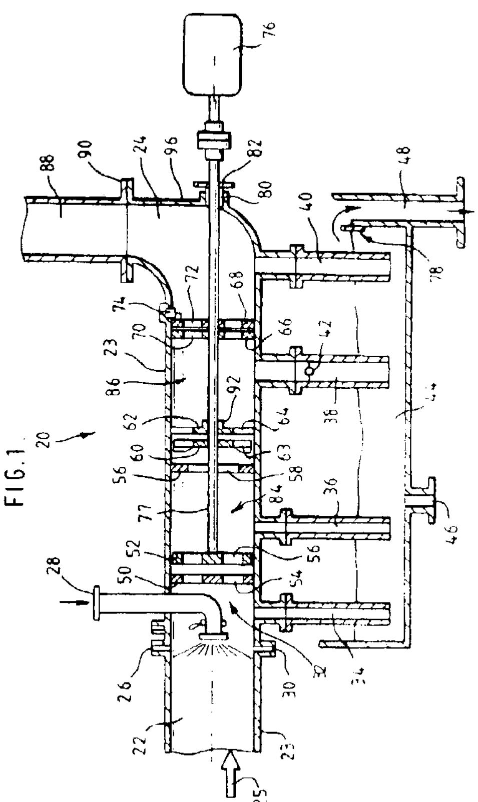

FIG. 1

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1. Technical Field

The present invention broadly relates to methods and devices for treating fluent materials for purposes of mixing, reacting, conditioning and the like, and deals more particularly with a method and apparatus of this general type which imparts turbulence to the fluent materials through the use of mechanical shock.

2. Description of Prior Art

The fluid treatment art is replete with improved mechanical, pneumatic, hydraulic and electrical systems for mixing, agitating, reacting and conditioning fluent materials. In some of these systems, such as those dedicated to mixing operations, operating efficiency and effectiveness is dependent upon the level of mass transfer of the fluent materials being mixed. Mass transfer is a function of the probabilities that particles/molecules of the differing fluent materials being mixed are exposed to each other, and this exposure depends in part upon the surface area presented by the particles/molecules of the different materials. In order to increase the probabilities for complete dispersal of the materials, mixing time may be increased. This alternative is available in the case of "batch" processing but may not be feasible in continuous type mixing processes where the resident time of the fluent materials in a mixing vessel is necessarily limited. Moreover, extending the duration of mixing or applying excessive amounts of energy in the mixing process may result in fracturization or excess micro-pulverization, producing undesirable fine dust or even degradation of the component parts of the materials being processed.

Various improvements have been devised to facilitate more efficient mixing and increase dispersion rates. For example, a device typifying one common solution to this problem is disclosed in U.S. Patent No. 4,874,248 issued October 17, 1989 to Luetzelschwab. The Luetzelschwab device comprises a plurality of alternately arranged, stationary and rotating disks within a cylindrical housing which is intended to be employed for continuously mixing a gel and a liquid. The disks contain apertures through which the gel and liquid flow in order to break down the gel into smaller particles and increase the gel surface exposed to the liquid. Prior art mixers of this type, while adequate for certain specific applications, provide less than satisfactory efficiency in other applications. Besides, the fraction is by cutting instead of shocks. In some cases, the requisite degree of mixing may be achieved only with long resident times in the mixer, thus dictating, in the case of continuous type processes, a mixer of large physical dimensions in order to provide a long flow path within the mixer. Physically large mixers normally add to expense and typically consume larger amounts of energy to operate.

Numerous types of processes are known for treating fluent materials to alter/improve their physical characteristics which involve the direct application of pulses or waves of energy to the materials. For example, U.S. Patent No. 4,957,606 issued September 18, 1990 to Juvan discloses a process for separating substances from liquids using high energy discharge initiated shock waves. U.S. Patent No. 4,961,860 issued October 9, 1990 to Masri discloses a water treatment process in which the water is subjected to ultrasonic vibrations producing cavitation of water through a fluid flow passage. The use of acoustical energy in standing waves for manipulating and separating fluent particles is also disclosed in U.S. Patent Nos. RE33,524; 4,877,516 and 4,983,189.

Summary of the Invention

According to one aspect of the invention, a method for treating fluent materials comprises introducing a flow of the fluent materials into a housing, and imparting pulses of energy to the fluent material by successively passing incremental quantities of the fluent materials in bursts from a relatively highly pressurized fluid zone through a pressure reducing baffle arrangement into a turbulent area downstream from the baffle arrangement. The baffle arrangement comprises a pair of baffle plates having orifices therein which periodically register with each other when one plate is rotated relative to the other. Rotation of one of the plates relative to the other allows discrete quantities of fluent materials to flow through the orifices into the turbulent area, thus cyclically changing the rate of fluid through the housing. The step of passing the fluent materials through orifices in baffle plates into a turbulent area is repeated at a second treatment stage downstream from the first turbulent area to impart additional turbulence to the fluent material. Vibratory energy may be applied to the fluent materials prior to the pulsation steps in order to pre-excite and agitate the fluent materials.

According to another aspect of the invention, apparatus is provided for treating fluent materials comprising housing means including an inlet for receiving the fluent material and an outlet, and pulsing means within the housing for imparting turbulence to the fluent materials, including orifice means for passing incremental quantities of the fluent materials in bursts from a relatively high fluid pressure zone into a turbulent area. The pulsing means includes a pair of closely spaced baffle plates each including a plurality of openings defining the orifice means. One plate is stationary while the other is rotated so as to periodically shift the openings in the two plates into registration with each other in order to allow bursts of the materials to flow into the turbulent area, thus imposing mechanical pulses of energy on the fluent materials

to alter their physical characteristics, either at the particulate or molecular level. A fluid pump in the form of a motor drive impeller may optionally be employed within the housing to assure a proper rate of flow of the materials through the housing. A reed-type element disposed in the flow path at the upstream end of the housing and tuned to vibrate under the influence of the flow of fluent materials therepast imparts vibrational energy to the fluent materials priority to passing through the rotating baffle plates.

It is therefore an important object of the present invention to provide a method and apparatus for treating fluent materials which is highly effective in imparting a level of energy to the materials sufficient to alter their characteristics at the particle or molecular level and thereby render them more suitable for segregation, mixing, etc.

Another object of the invention is to provide a method and apparatus of the type generally mentioned above which is exceptionally compact in size, requires minimal energy to operate and significantly reduces resident time of the fluent materials therein for processing.

A still further object of the invention is to provide a method and apparatus of the type described which is highly reliable and simple in its component parts, thus simplifying and reducing the expense of repair and maintenance.

A further object of the invention is to provide a method and apparatus of the type mentioned which provide continuous mixing of materials while achieving intimate interaction between component parts of the materials being mixed to enhance homogeneity and consistency of the mixture, with minimum residence time in the mixing apparatus.

These, and further objects and advantages of the present invention will be made clear or will become apparatus during the course of the following description of the preferred embodiments of the present invention.

Brief Description of the Drawings

In the drawings, which form an integral part of the specification and are to be read in conjunction therewith, and in which like-reference numerals are employed to designate identical components in the various views:

Figure 1 is a combined diagrammatic and longitudinal sectional view of one embodiment of an apparatus for carrying out the method of fluent material treatment according to the present invention;

Figures 2 and 3 are side views of two alternate forms of the apparatus shown in Figure 1;

Figures 4A-4G are, respectively, front elevational views of alternate embodiments of rotatable baffle plates which may be employed in the apparatus of Figure 1;

Figures 5A-5G are, respectively, front elevational views of alternate embodiments of stationary baffle plates which may be respectively paired with the baffles plates of Figures 4a-4g and employed in the apparatus of Figures 1;

Figure 6 is a longitudinal cross-sectional view of apparatus for treating fluids in accordance with the preferred embodiment of the present invention;

Figures 7a-7h are perspective views, respectively of alternate forms of the vibrating elements employed by the apparatus of Figure 6;

Figure 8 is perspective view of the fluid pump employed in the apparatus of Figure 6;

Figures 9 and 10 are exploded, cross-sectional views showing the details of the bearings employed respectively at opposite ends of the apparatus of Figure 6; and

Figure 11 is a graph depicting the rate of flow of fluid through the apparatus of Figures 1 and 6, as a function of time.

Description of the Preferred Embodiments

Attention is first directed to Figure 1 which depicts an apparatus, generally indicated by the numeral 20 for treating fluent materials. As used herein, "fluent materials" means any materials which are flowable or exhibit fluid properties, including liquids, gases, particulates, and the like, or any combination thereof, in any physical state. The apparatus 20 illustrated in Figure 1 is an embodiment of the invention particularly well-suited for performing mixing of two or more fluent materials, however, it is to be understood that the method and apparatus of the present invention may also be employed for treating a single fluent material to condition the material for subsequent use or processing.

The apparatus 20 includes a generally cylindrical housing 23 having a main inlet 22 at one end thereof for receiving fluent materials. The opposite end of the housing 23 includes an end wall 96, and a main outlet 24 which extends transversely outward relative to the longitudinal axis of the housing 23. The main outlet 24 is coupled by a flange 90 to a pipe 88 delivering treated fluent materials to a subsequent process, or use. In addition to the main inlet 22, additional secondary inlets may be provided for introducing additional fluent materials into the housing 23, three of such secondary inlets being respectively indicated at 26, 28 and 30. Secondary inlets 26 and 30 are defined in the sidewalls of the housing 23, while inlet 28 is formed by a tube extending through the sidewall of housing 23, which includes an outlet disposed at the central axis of the housing 23 and oriented to introduce the fluent material upstream, in opposition to the main flow, designated by the numeral 25, thus tending to

evenly disperse the secondary fluent material into the main stream of flow. In any event, the secondary fluent materials are combined with the main flow at a premixing area 32 immediately before entering a first treatment stage defined by baffle means in the form of a pair of circular plates 50, 52 and a turbulent zone 84 immediately downstream of plates 50, 52. The baffle plates 50, 52 oppose the flow of fluent materials through the housing 23 and are preferably spaced as closely to each other as possible. Baffle plate 50 is disposed upstream of plate 52 and is stationarily secured around its periphery to the interior sidewall of the housing 23. Plate 50 is coextensive with the cross-section of the housing 23 and includes a plurality of later discussed openings 54 therethrough, evenly spaced and distributed around the central axis thereof. Baffle plate 52 is secured at its central axis to one end of the rotatable shaft 77 for rotation therewith. The diameter of the rotatable baffle plate 52 is just slightly less than that of the inside diameter of the housing 23 to provide adequate clearance therebetween. A plurality of circumferentially spaced openings 56 are provided in the rotatable baffle plate 52, the configuration of which will be discussed later in more detail. The sets of openings 54, 56 in plates 50 52 are configured and positioned so as to periodically shift into aligned registration with each other as the shaft 77 is rotated at a preselected frequency by a motor 76.

The shaft 77 extends through end wall 96 of the housing 23 and has one end thereof journalled for rotation in a bearing 80 provided with a seal 82 to prevent the escape of fluent materials therethrough. The shaft 77 is rotated by a motor 76 which may be of a conventional electrical, pneumatic, hydraulic, or internal, or external combustion type.

A second fluent material treatment stage, downstream of the earlier discussed stage, comprises a second pair of circular baffle plates 60, 62, and a second cavitation area 86 downstream therefrom. Plate 60 is secured to the shaft 77 for rotation therewith, while plate 62 is stationarily secured to the interior wall of the housing 23. The rotatable plate 60 is essentially coextensive with the cross-section of the housing 23, with only enough clearance around its periphery to permit free rotation thereof. Plates 60 and 62 respectively include first and second sets of circumferentially spaced openings, 63 64 therethrough which are arranged so as to periodically shift into aligned registration with each other as the shaft 68 rotates, thereby allowing incremental quantities of the fluent material to flow in burst therethrough into the cavitation area 86. The fixed baffle plate 62 includes a bearing 92 therein for rotatively supporting the shaft 77 intermediate its opposite ends.

A pressure balancing baffle plate 57 is stationarily secured within the housing 23 immediately upstream of the second treatment stage. The baffle plate 57 is ring-shaped, having a central opening 58 therein, and presents a surface area opposing flow of the fluent materials which is sized to prevent an inordinate drop in fluid pressure (due to low pressure in the cavitation area 84) before the flow enters the second treatment stage. In a similar manner, the fluid pressure downstream of the second cavitation area 86 may be controlled, as required, by a flow control valve defined by a stationary plate 66 and a movable plate 68 respectively provided with openings 70, 72 therethrough. A conventional valve control 74 such as an endless screw, gear, rack or the like is employed to rotate plate 68 relative to plate 66 thereby adjusting the registration of openings 70, 72, and thus controlling the flow therethrough as well as the fluid pressure within the second cavitation area 86.

Any of the fluent materials or components thereof may be removed at any desired location during flow through the housing 23 by means of a series of purge lines 34, 36, 38, 40. In the embodiment illustrated in Figure 1 purge line 34 diverts fluent material from the premix area 32, purge line 36 diverts material from the first cavitation area 84, purge line 38 diverts material from the second cavitation area 86 and purge line 40 diverts material immediately before it leaves the apparatus 20 through the main outlet 24. The purge lines 34-40 may be valve controlled, if desired. A butterfly valve 42 has been shown for illustrative purposes in purge line 38. Purge lines 34-40 may deliver materials diverted thereby into a common tank or decanter 44 provided with a purge line 46 in the bottom thereof. An overflow line 48 may be employed to draw-off excess quantities of materials accumulated in the tank 44, and a conventional level control 78, such as a slide gate cooperates with the overflow line 48 to maintain a desired level of material in the tank 44.

Figure 2 depicts a slightly modified form of the apparatus 20, wherein the housing 23 is provided with a second end wall 98 opposite end wall 96, and the main inlet 22 extends essentially perpendicular to the axis of the housing 23, downwardly as depicted in Figure 2, opposite the direction of the outlet 24. The main inlet 22 shown in Figure 2 is connected by a flange 102 to a supply pipe 94. A further modified form of the apparatus 20 is shown in Figure 3 wherein the main inlet in likewise oriented essentially perpendicular to the central axis of the housing 23 but extends upwardly in a direction parallel to that of the outlet 24. In the case of both Figures 2 and 3, the provision of the second end wall 98 allows the shaft 77 to be supported at its outer end by means of a bearing 100 mounted on the end wall 98, with a seal 101 between the housing 23 and the shaft 10.

Attention is also now directed to Figures 4A-G and 5A-G which illustrates a few of the possible configurations of the openings provided in the baffle plates 50, 52, 60, 62. Specifically, Figures 4A-G depict suitable opening configurations for rotatable baf-

fle plates, i.e., baffle plates 52 and 60, while Figures 5A-G depict suitable configurations for fixed baffle plates, i.e., baffle plates 50, 62. The plates shown in Figures 4A-G and 5A-G respectively form matched pairs of rotatable and fixed baffle plates, e.g., the plates shown in Figures 4A and 5A form a matched pair of a rotatable and fixed plate, respectively which could be employed in either the first or second treatment stages, as plates 50, 52 or 60, 62. As can be seen from Figures 4A-G and 5A-G, the openings 54, 56, 63, 64 are discrete geometric shapes uniformly distributed in circumferentially spaced relationship about the central axis of each plate. The shape of the openings 54, 56, 64, 64 may take the form of triangles (Figs. 4A-5A), squares (Figs. 4B-5B), hexagons (Figs. 4C-5C), circles (Figs. 4D-5D), rectangles (Figs. 4E-5E), truncated segments (Figs. 4F-5F) or fan-shaped segments (Figs. 4G-5G). Numerous other shapes of openings 54, 56, 63, 64 may also be employed, and the particular configuration selected is dependent in part on the specific application of the apparatus 20. In any event, it may be seen from Figures 4A-G and 5A-G that rotation of one plate relative to the other results in periodic juxtaposition of the openings in the pairs of baffle plates from a flow blocking relationship to an aligned, registered relationship permitted the flow of fluent materials therethrough.

Turning now to the operation of the apparatus 20, fluent materials comprising gases, liquids, dust/particulates or any combination thereof are delivered either through the main inlet 22 or any of the secondary inlets 26-30 and become preliminary mixed in the premix area 32, immediately upstream of the first treatment stage. The flow of fluent materials either through the main inlet 22 or secondary inlets 26-30 is delivered under pressure produced either from an upstream pressure source such as a pump (not shown) or other means of providing a sufficient head to overcome any pressure drops experienced during the course of flow through the housing 23. Alternatively, the necessary fluid flow pressure may be generated by means of a pump or the like either downstream of the outlet 24 or integrated internally within the housing 23. By way of example and not limitation, a typical application of the embodiment of the apparatus 20 shown in figure 1 may require a flow pressure of between 8 mm of water column up to 40 Kg/cm^2, independent of consistency, temperature or viscosity of the fluent materials.

As the shaft 77 is rotated by the motor 76, the identically configured openings 54, 56 respectively in baffle plates 50, 52 are periodically rotated between a non-aligned, flow-blocking relationship, and an aligned coextensive relationship permitting the flow of an incremental quantity of fluent material therethrough, from the premixing area 32 into the cavitation area 84. The cavitation of the fluid flow in cavitation area 84 of course results from the baffling effect of plates 50, 52 and the periodic nature of flow through baffle plates 50, 52. The incremental quantities of fluent material thus flow through the aligned openings 54, 56 in bursts from an area of relatively high pressure (premix area 32) to an area of relatively low pressure (cavitation area 84), resulting in pulses of energy being imparted to the fluent materials. As will be discussed later in more detail, these pulses of energy imparted to the fluent materials tend to breakdown and/or disorder particulates, aggregations of molecules or chains of molecules and the molecules themselves into a very homogeneous dispersion. Where multiple fluent materials are introduced into the apparatus 20 for mixing, the pulses of energy applied to the mixture in !he manner described above results in disordering of the molecules of the fluent materials that otherwise tend to be attracted toward each other by weak bonding forces, thus increasing the exposed surface areas of the molecules to thereby increase mass transfer and obtain a more complete, homogeneous mixture.

The rate at which pulses of energy are applied to the fluent materials by both the first and second treatment stages is dependent upon the number, size and spacing of the openings 54, 56, 63, 64 and the baffle plates 50, 52, 60, 62 as well as the rotational speed of the shaft 77. These parameters are chosen to suit the particular application of the apparatus 20, taking into consideration the characteristics of the fluent materials to be treated. By way of illustration, however, the frequency of pulsation may range from 5 Hz to 100 KHz for a range of typical applications.

In some applications, passing the fluent materials through a single treatment stage may be adequate to achieve the desired results, while other applications may require tow or more stages to obtain satisfactory results. In the event of a multiple treatment stage arrangement, such as is shown in the embodiment of Figure 1, it may be necessary to compensate for the effects of the significant pressure drop in the fluid flow occasioned by the effects of cavitation, as in the first cavitation area 84, before the flow is delivered to a subsequent treatment stage. Thus, in the embodiment of Figure 1, the pressure regulating baffle plate 57 provided with a flow-through opening 58 compensates for the pressure drop is cavitation area 84 by building up the pressure of the fluid immediately before it passes through the second treatment stage defined by baffle plates 60, 62 and the second cavitation area 86. Therefore, fluent materials at a relatively high pressure level pass through the openings 63, 64 is baffle plates 60, 62 in periodic bursts of fluid flow, into an area of relatively low fluid pressure defined by the cavitation area 86. In this respect, the second treatment stage functions much like the first treatment stage described earlier, to impart pulses of energy to the fluent material, thereby further disor-

dering them on a molecular level to effect mixing thereof and/or condition the fluent materials for subsequent use or processing after exiting the housing 23. It may be noted hereto that the rotatable baffle 60 is disposed on the upstream side of the stationary baffle 62, unlike the first treatment stage wherein the stationary baffle 50 is on the upstream side of the rotating baffle plate 52; the order of the fixed and rotating baffle plates in each pair thereof is not significant.

The flow control valve formed by the plates 66, 68 may be adjusted to alter the flow pressure at the outlet 24 and may be employed to adjust the upstream pressure and optimize the effects of the first and second treatment stages on the fluent materials.

Purge lines 34-40 may be optionally employed to divert portions or byproducts of the fluent materials before, during and after they are processed by the first and second treatment stages.

Reference is now made to Figures 6, 8, 9 and 10 which depict a preferred form of the apparatus of the present invention, generally indicated by the numeral 200, in Figure 6. The apparatus 200 broadly includes a generally cylindrical housing 202, a radially directed primary inlet 204 at one end of the housing 202, and a radially directed primary outlet 206 at the opposite end of the housing 202. The inlet 204 and outlet 206 are respectively provided without mounting flanges 220, 222 for connection with conduits (not shown) or the like of other components in a system in which the apparatus 200 is integrated. Inlet 204 is adapted to receive fluent materials from a source (now shown) in the direction of the arrow 262 toward a premix area designated by the numeral 212 which immediately precedes a first treatment stage which will be discussed below. Additional fluent materials, identical to or different from the materials introduced through the primary inlet 204, may be introduced through secondary inlets 208, 210 defined in one end wall 218 of the housing 202. Inlets 208, 210 may comprise, for example, spray nozzles for introducing liquids to be mixed with fluent materials introduced through the primary inlet 204. A reed-like dispersing element 214 mounted on a stem 216, is disposed immediately downstream of and aligned with the incoming flow of fluent materials introduced through the secondary inlets 208, 210. The dispersing elements 214, as shown in Figure 6, are formed of thin, rectangularly-shaped flexible metal which, under the influence of fluent material flowing therepast, vibrate at a preselected frequency. The dispersing element, which may be of various types, tends to excite and agitate the material flow so as to better mix with the fluent material introduced through the primary inlet 204. The precise resonant frequency, size and configuration of the vibrating elements 214 will depend upon the particular application. However, by way of example, several typical alternate shapes for the vibrating element 214 are depicted respectively in Figures 7A-H. Figures 7A-H respectively show dispersing elements 214 configured in the shapes of a cone, a pyramid, a star, oval, toothed disk, rectangle with an increased amount of thickness, circular, and finally pie crust edge-like configuration.

A shaft 224 extends longitudinally through the central axis of the housing 202 and is journalled for rotation at its opposite ends by bearings 226, 320. The ends of the shaft 224 are threaded to receive lock nuts 232, 322 which restrain the shaft 224 against longitudinal movement. A keyway 308 in one end of the shaft 224 adapts the shaft 224 to be connected with a source (not shown) of rotational power, such as an electric, hydraulic or, pneumatic internal or external combustion engine motor. Bearing 226 is disposed within a bearing pack 230 provided with a removable cap 235. Similarly, bearing 320 is disposed within a bearing pack 325 provided with a removable cap 324 having a central opening thereof through which one end of the shaft 224 extends.

Bearing pack 230 is mounted within the outer end of a hub 228 which includes a peripheral portion 215 secured to the end wall 218, and thus forms the main structural support for one end of the shaft 224. A conically-shaped, protective bearing boot 234 includes a flange 245 for mounting the boot 234 to the end wall 218. The boot 234 extends into the housing 202 and includes a plurality of sealing rings 244 surrounding the shaft 224 to assist in sealing and isolating the bearings 226 from the environment within the housing 202.

A cylindrically-shaped ring gate 236 disposed in the premix chamber 212 surrounds the shaft 224 and includes a partial bottom wall 246. The ring gate 236 is concentrically disposed within and is overlapped by a ring-shaped deflector 255 which extends inwardly from the end wall 218 toward the premix area 212. The ring gate 236 is mounted for longitudinal sliding movement relative to the deflector ring 255 by means of slidable stud shafts 238 which extend through openings in the end wall 218 and supports 242. The outer ends of the sliding shafts 238 are threaded to receive nuts 240 which lock the ring gate 236 in a desired longitudinal position relative to the deflector ring 255. Motor means (not shown) can be connected, if desired, to the outer ends of the sliding studs 238 to provide automatic longitudinal displacement of the ring gate which functions to alter the amount and flow of fluent materials entering the mixing area 212.

The motor-driven end of the shaft 224 is structurally supported on the housing 202 by means of a support hub 318 which houses the bearing pack 325 in the outer end thereof. The hub 318 includes an outer flange 319 secured to end wall 321. In order to protect the bearing 320 from the environment within the housing 202, there is provided a bearing boot 310 disposed within the housing 202 and mounted on the

end wall 321 by means of an outer flange 327. The protective bearing boot 310 includes a pair of longitudinally spaced seals 312, 314 each including a plurality of ring seals engaging the shaft 224 to prevent fluent materials and the like within the housing 202 from passing through the boot 310 to the bearing 320. Between the seals 312, 314, a chamber 329 is provided for receiving a pressurized fluid, such as water or air from a supply inlet 316. The pressurized fluid within chamber 329 tends to equalize and oppose the fluid pressure within the housing 202 which urge the fluent materials to enter the seal 312.

A cylindrically-shaped slide ring 288 is secured to sliding studs 290 extending through openings in the end wall 321. Sliding studs 290 have their outer ends threaded to receive nuts 292 which bear against mounting bosses 294 in order to lock the slide ring 288 in a desired longitudinal position, surrounding the shaft 224, immediately upstream of the outlet 206. The slide ring 288 cooperates with a partition wall 296 and a deflecting wall 298 to adjust the amount and direction of flow toward the outlet 206. Motor means (not shown) can be coupled with sliding studs to provide automatic motorized control of the position of the slide ring 288.

A first treatment stage, immediately downstream of the premix area 212, broadly comprising a rotatable baffle plate 248, stationary baffle plate 250 and a cavitation chamber 258. Rotatable baffle plate 248 includes a hub 256 secured to shaft 224 for rotation therewith, and a plurality of radially extending blades having openings 252 therebetween, similar in geometry to the arrangement depicted in Figure 4G. The stationary baffle plate 250 is closely spaced to and downstream of the rotatable baffle plate 248, and has its outer periphery secured to the interior wall of the housing 202. The stationary baffle plate 250 is provided with a plurality of openings 254 therein which are arranged similar to the configuration shown in Figure 5G, previously discussed. The longitudinal spacing between plates 248 and 250 is as small as possible to minimize any flow of fluent material in a radial direction, therebetween. Similarly, the inner edges of the stationary baffle plate 250 are positioned as closely around the shaft 224 as is feasible in order to prevent the flow of fluent materials through this gap, rather than through the openings 254. As previously discussed, the shape, size and number of the openings 252, 254, in combination with the rotational speed of the shaft 224 are selected based upon the particular application and use of the apparatus 200, so as to produce pulsation of the fluent materials at a desired frequency.

Bursts of fluid incrementally passing through the openings 252, 254 flow through the cavitation chamber 258 in the direction of the arrows 260 toward a second fluent material treatment stage broadly comprising a rotating baffle plate 264 mounted on shaft 224 by a hub 284, and a stationary baffle plate 266 having its outer periphery secured to the interior wall of housing 202. Baffle plates 264, 266 respectively include a plurality of openings 268, 270 therein which may be of any of the configurations respectively shown in Figures 4A-G and 5A-G. As best seen in Figure 6, the openings 268, 270 are radially-spaced somewhat outbound of the openings 252, 254 contained in the plates 248, 250 of the first treatment stage, thus forcing the fluid to alter its course somewhat as it flows from the first to the second treatment stages. Incremental qualities of the fluent materials passing through the openings 268, 270 in bursts enter the second cavitation chamber 272 and thence are drawn through a fan-type impeller pump 280.

The pump 280 includes an outer deflection ring 282 surrounding the impeller 280 which is mounted by a hub 286 for rotation on the shaft 224, along with the rotating baffle plates 248, 264. The pump 280 is optionally employed to generate the necessary fluid pressure/vacuum within the housing 202 to force proper flow of fluent materials therethrough. Such pump may alternately be provided, however, as a separate component connected with either the inlet 204 or outlet 206. A concentrical stationary ring shape plate 278 is used between the impeler inlet of the pump 280, and the housing 202, being secured to the interior wall of the housing 202 and closely spaced to the impeller inlet so the flux passes through the pump.

A further fluid material inlet 274 in the housing 202 is positioned immediately downstream of the second treatment stage and allows the introduction of additional fluid material to be introduced into the cavitation chamber 272. A further reed-like vibrating element 276 may be provided at the inlet 274 to aid in agitation and preconditioning of the fluent material entering the inlet 274 to aid in its mixing with other fluent materials passing through the second treatment stage.

A plurality of purge outlets 300, 302, 304 and 306 are provided at longitudinally-spaced locations in the wall of the housing 202 to permit diversion of portions of the fluent material at intermediate stages of treatment thereof, and to aid in cleaning the apparatus 200.

The operation of the apparatus 200 shown in Figure 6 is fundamentally similar to that of the apparatus 20 shown in Figure 1. Fluent material entering inlet 204 is combined with fluent materials entering secondary inlets 208, 210, in the premix area 212 prior to passing through the first treatment stage. As the shaft 224 rotates, openings 252, 254 in baffle plates 248, 250 periodically come into alignment with each other to allow bursts of the fluent materials to pass therethrough and into the cavitation area 258 where the fluid pressure is substantially less than that in the premix area 212. These bursts of fluid flow are thus

cyclical in nature and result in imparting pulses of energy to the fluid at a desired frequency.

The fluent material then passes through the second treatment stage comprising baffle plates 264, 266 and cavitation chamber 272. Again, the fluent material passes through openings 268, 270 when the latter are aligned so as to permit period bursts of the materials to flow into the second cavitation chamber 272, thus imparting a second series of energy pulses to the fluent materials at a frequency which is not necessarily the same as, and indeed is preferably different than the frequency of energy pulses imparted by the first treatment stage.

The fluent material is then drawn by the impeller pump 280 past the slide ring 288 through the outlet 206. Flow rates and fluid pressures through the apparatus are controlled in part by changes in the pressure of the fluent materials entering the inlet 204, longitudinal positioning of the ring gate 236, the amount of additional fluent material and the pressure thereof entering through secondary inlets 208, 210 and 274, as well as longitudinal positioning of the slide ring 288.

Figure 11 is a plot of the flow rate as a function of time for fluent material passing through the apparatus 20. From figure 11 it can be seen that the flow rate oscillates in magnitude as a result of the pulsation action produced in the first and second treatment stages. The oscillatory nature of the flow rate is not unlike an alternating electrical current, and it is this sharp change in flow rate as a function of time that results in energy being imparted to the fluent materials which results in molecular conditioning to facilitate mixing or other processing of the materials.

From the foregoing, it is apparent that the method and apparatus of the present invention described above not only provide for the reliable accomplishment of the objects of the invention but do so in a particularly reliable and simple manner. It is recognized, of course, that those skilled in the art may make various modifications or additions chosen to illustrate the invention without departing from the spirit and scope of the present contribution to the art. Accordingly, it is to be understood that the protection sought and to be afforded hereby should be deemed to extend to the subject matter claimed and all equivalents thereof fairly within the scope of the invention.

Claims

1. A method for mixing two or more fluent materials, comprising the steps of:
   (A) introducing a pressurized flow of said fluent materials into a housing; and,
   (B) imparting pulses of energy to said fluent materials by successively passing incremental quantities of said fluent materials in bursts from a high pressure zone to a low pressure zone within said housing.

2. The method of Claim 1, wherein step (B) is performed by periodically passing said incremental quantities of said fluent materials through openings in a baffle arrangement within said housing.

3. The method of Claim 1, wherein step (B) is performed by:
   restricting the flow of said fluent materials from said high pressure zone to said low pressure zone; and
   periodically relieving the flow restriction of said fluent materials to allow passage of said incremental quantities of said fluent materials in said pulses.

4. The method of Claim 3, wherein:
   said flow restricting substep is performed by providing baffle means within said housing for opposing said flow, and
   said relieving substep is performed by periodically opening a portion of said baffle means.

5. The method of Claim 4, wherein the opening of a portion of said baffle means is performed by relatively moving first and second sets of openings in said baffle means periodically between a first position preventing flow of said fluent materials therethrough, and a second position allowing flow of said fluent materials therethrough.

6. The method of Claim 4, wherein the ;opening of a portion of said baffle means is performed by relatively rotating a pair of baffle plates respectively having first and second sets of openings therein such that said first and second sets of opening are alternatively shifted into and out of registration with each other.

7. The method of Claim 6, wherein the relative rotation of said baffle plates is performed by holding one of said baffle plates stationary and rotating the other of said baffle plates relative to said first baffle plate.

8. The method of Claim 4, including the step of: (C) premixing said fluent materials within said housing before carrying out step (B).

9. The method of Claim 8, wherein step (C) is performed by receiving said fluent materials respectively through separate inlets in said housing into a premixing zone within said housing.

10. The method of Claim 1, wherein step (B) is performed at each of first and second treatment

areas within said housing.

11. The method of Claim 10, wherein the passing of fluent materials in bursts in step (B) is performed at two different frequencies respectively at said first and second treatment areas.

12. The method of Claim 1, wherein step (B) is performed by:

baffling the flow of said fluent materials through said housing using at least a first pair of baffling plates to produce said high and low pressure zones, and,

periodically shifting openings in said baffle plates into registration with each other to allow said bursts of said fluent materials to flow therethrough.

13. The method of Claim 12, wherein the shifting of said openings is performed by rotating one of said plates relative to the other.

14. The method of Claim 13, wherein the shifting of said openings is performed by rotating one of said plates exposed to said high pressure zone and maintaining stationary the other of said plates exposed to said low pressure zone.

15. The method of Claim 11, wherein step (B) is performed by:

baffling the flow of said fluent materials through said housing at said first and second treatment areas respectively using first and second pairs of baffling plates, and,

rotating one of the baffling plates relative to the other baffling plate in each of said first and second pairs thereof relative to periodically shift openings in each of said first and second pairs of baffling plates into registration with each other to allow said bursts of said fluent materials to flow therethrough.

16. The method of Claim 1, including the step of:

(C producing vibrations in said fluent materials before performing step (B) by flowing said fluent materials past an oscillating member within said housing and disposed in the flow path of said fluent materials.

17. A method for treating fluent materials, comprising the steps of:

(A) introducing a pressurized flow of said fluent materials into a housing;

(B) producing a cavitation area within said housing by baffling the flow of said fluent materials through said housing using baffle means;

(C) periodically passing incremental quantities of said fluent materials in bursts through said baffle means in a manner to impart pulses of energy to said fluent materials.

18. Apparatus for treating a fluent material, comprising:

housing means including inlet means for receiving said fluent material, and outlet means;

pulsing means within said housing for imparting pulses of energy to said fluent material, including orifice means for passing incremental quantities of said fluent material in bursts from a high pressure zone to a low pressure zone.

19. The apparatus of Claim 18, wherein:

said pulsing means includes baffle means for restricting the flow of said fluent material through said housing, wherein said high and low pressure zones are respectively defined upstream and downstream of said baffle means, and

said orifice means is defined in said baffle means.

20. The apparatus of Claim 19, wherein:

said baffle means includes a pair of plates extending transverse to the flow of said fluent material through said orifice means,

said orifice means are defined in said plates, and

said pulsing means further includes means for rotating one of said plates relative to the other.

21. The apparatus of Claim 20, wherein:

said plates extend substantially parallel to and are closely spaced from each other, and

said orifice means includes first and second sets of openings respectively extending through and distributed around the central axes of said plates.

said first and second sets of openings being arranged to periodically register with each other as said one plate rotates relative to the other to allow a burst of said fluent material to flow through said plates from said high pressure zone to said low pressure zone.

22. The apparatus of Claim 21, wherein said pulsing means includes means for rotating said one plate.

23. The apparatus of Claim 22, wherein:

said rotating means includes a shaft and motor means for rotating said shaft,

said one plate is mounted on said shaft for rotation therewith, and

the other of said plates is stationarily mounted within said housing means.

24. The apparatus of Claim 21, including pump means within said housing means for creating a flow of fluent materials from said inlet means through housing past said pulsing means toward said outlet means.

25. The apparatus of Claim 18, including a premixing chamber within said housing means between said pulsing means and inlet means.

26. The apparatus of Claim 25, wherein said inlet means includes at least two inlets each adapted to receive a fluent material into said housing means.

27. The apparatus of Claim 18, wherein said pulsing means includes vibrator means upstream of said orifice and responsive to the flow of said fluent materials for imparting vibrational energy to the flow of said fluent materials.

28. The apparatus of Claim 27, wherein said vibrator means is disposed within the flow of fluent materials, between said inlet means and said orifice means.

29. The apparatus of Claim 18, wherein:

said pulsing means includes first and second spaced apart sets of baffle plates opposing the flow of said fluent materials through said housing means, one of the plates in each of said first and second sets thereof being closely spaced from and rotatable relative to the other plate, and

said orifice means includes a plurality of orifices in each of the plates in said first and second sets thereof, the orifices in the plates of each set thereof being arranged to periodically register with each other as said one plate in each set rotates relative to the other so as to alternate pass and block the flow of fluent materials through each set of plates.

30. Apparatus for treating fluent materials, comprising:

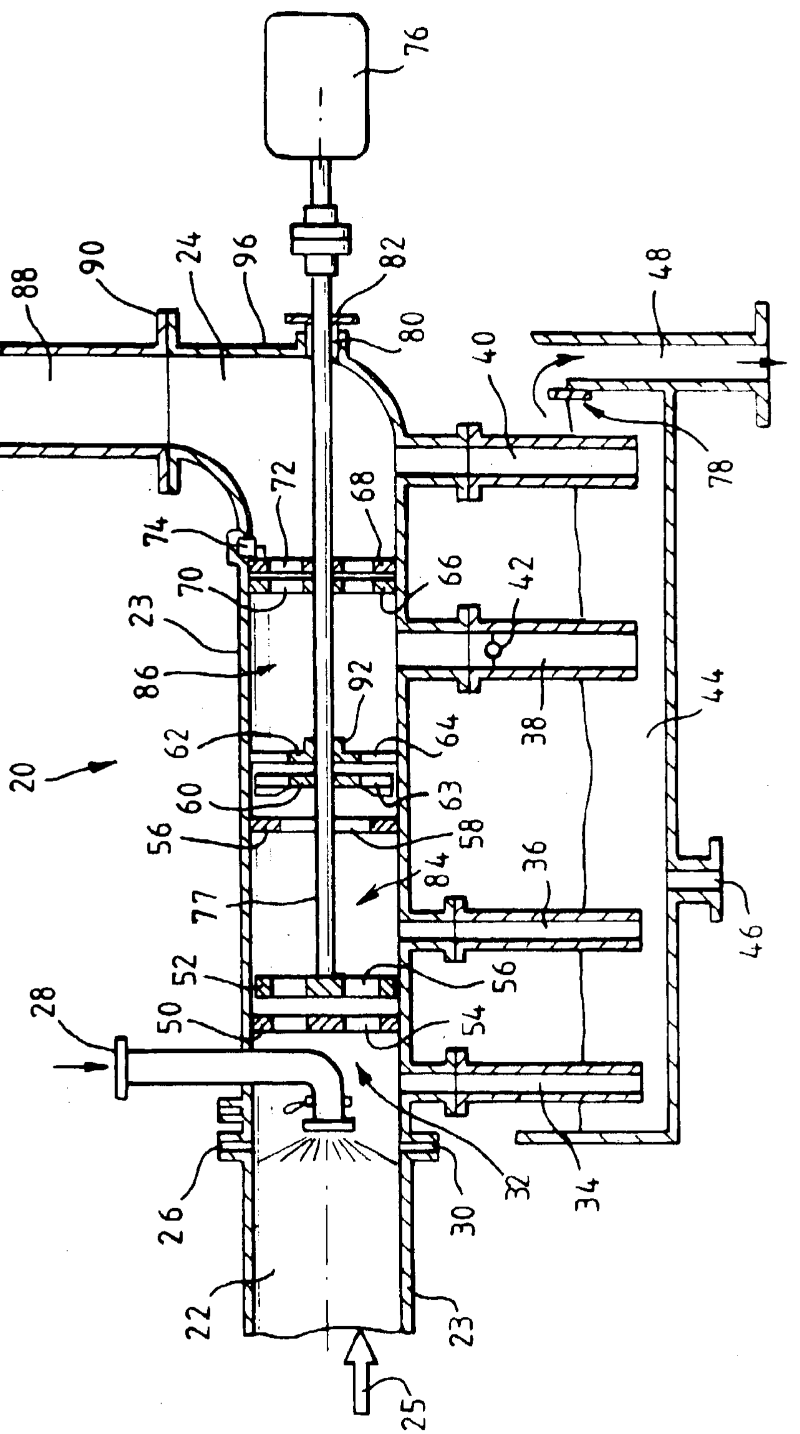
housing means including inlet means for receiving a pressurized flow of said fluent materials into said housing means, and outlet means for discharging said fluent materials from said housing means;

at least a first set of baffle plates within said housing means and opposing the flow of said fluent materials, said first set of baffle plates creating a decrease in the pressure of said fluent material across said baffle plates thereby defining a low pressure zone on the downstream side of said baffle plates, one of said baffle plates in said first set thereof being rotatable relative to the other;

a plurality of orifices in each of the baffle plates in said first set thereof, said orifices being arranged so as to periodically register with each other upon rotation of said one baffle plate to allow successive bursts of said fluent materials to pass through said first set of baffle plates into said low pressure zone; and,

means for rotating said one baffle plate relative to the other at a preselected speed, the bursts of fluent materials passing through said baffle plates into said low pressure zone imparting pulses of energy to said fluent material.

FIG.1.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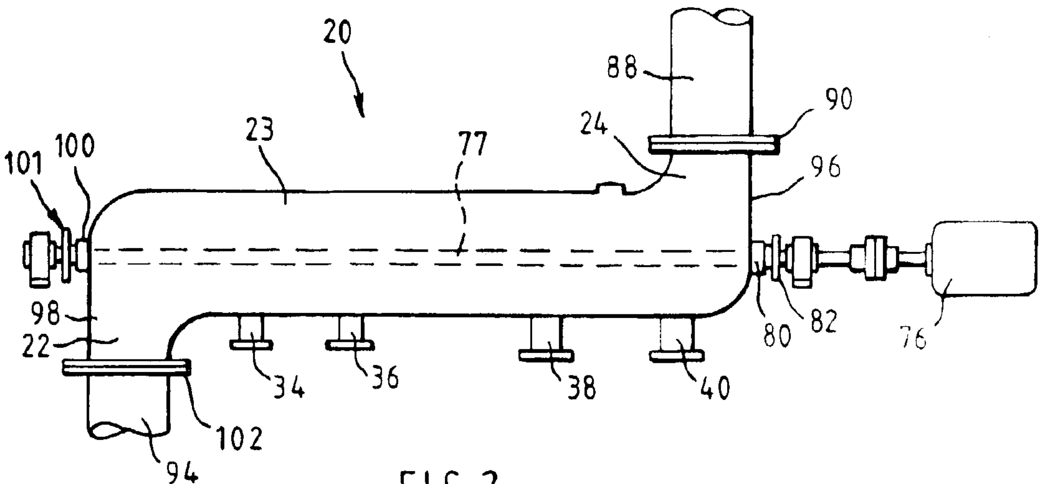
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FIG.2.

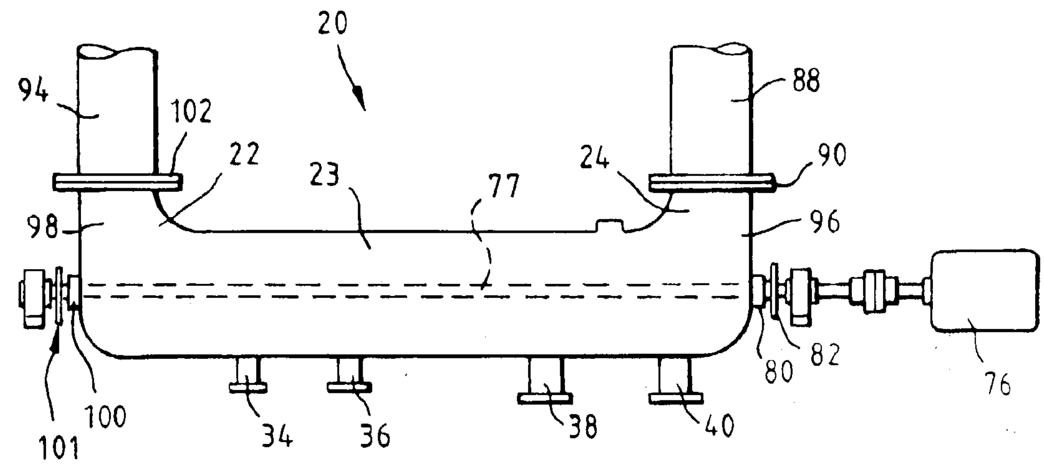
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FIG.3.

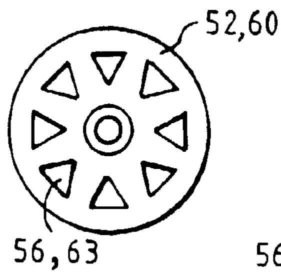

FIG.4A.

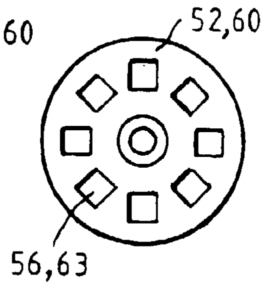

FIG.4B.

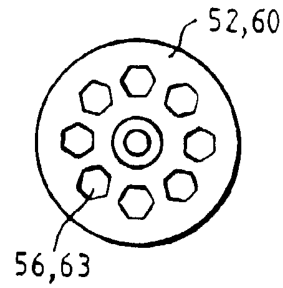

FIG.4C.

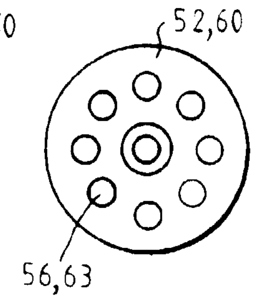

FIG.4D.

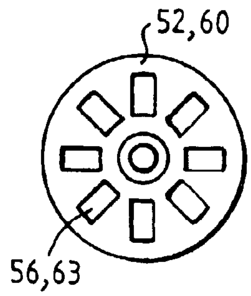

FIG.4E.

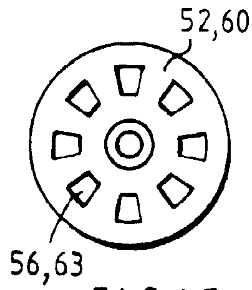

FIG.4F.

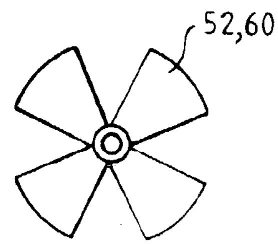

FIG.4G.

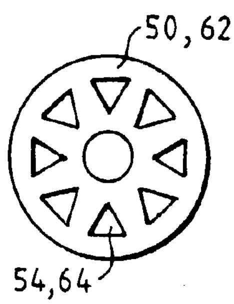

FIG.5A.

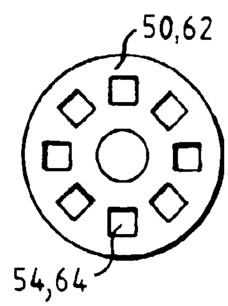

FIG.5B.

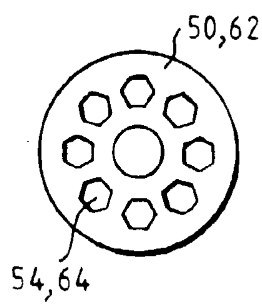

FIG.5C.

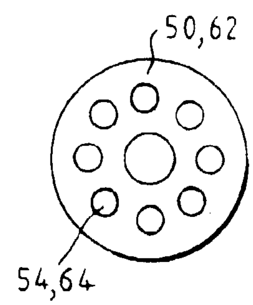

FIG.5D.

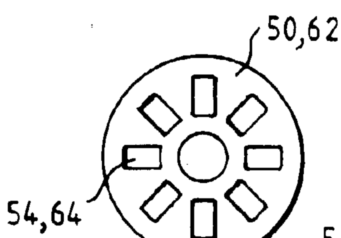

FIG.5E.

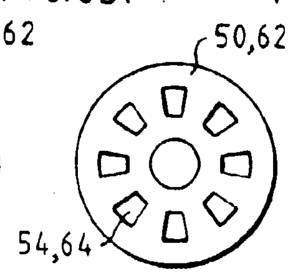

FIG.5F.

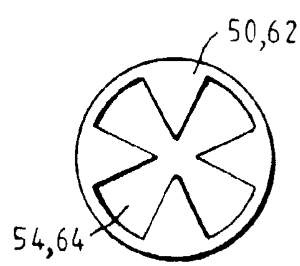

FIG.5G.

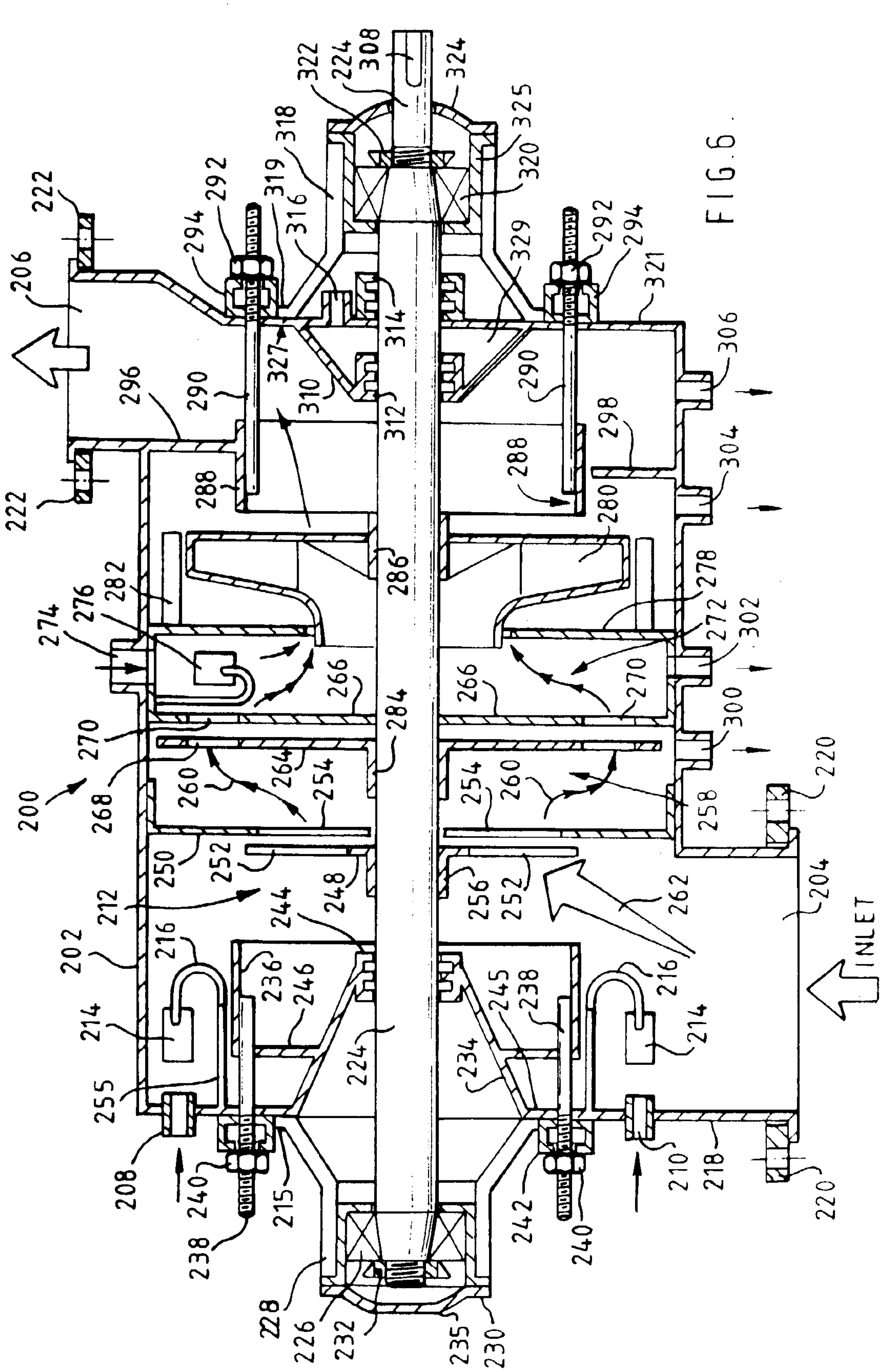
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FIG.6

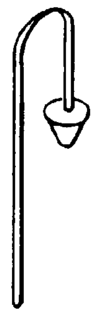

FIG.7A.

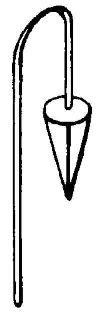

FIG.7B.

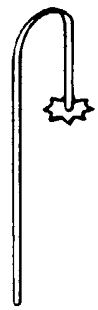

FIG.7C.

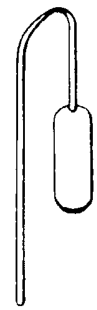

FIG.7D.

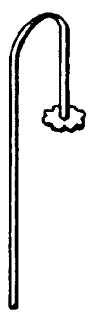

FIG.7E.

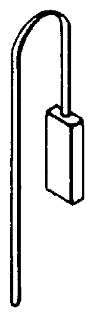

FIG.7F.

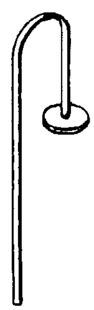

FIG.7G.

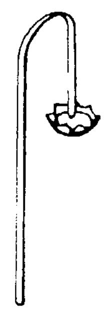

FIG.7H.

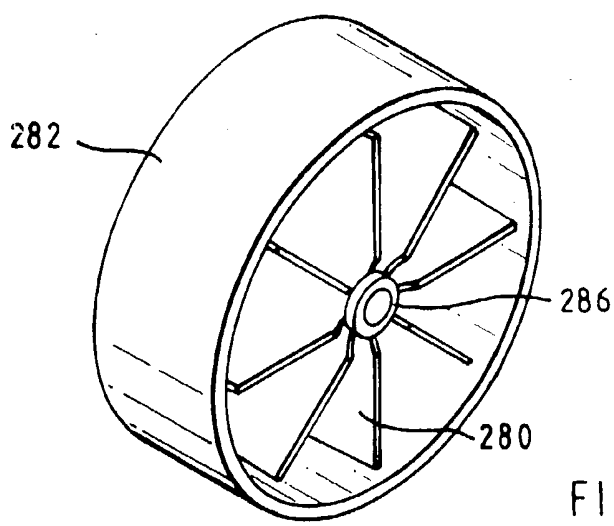

FIG.8.

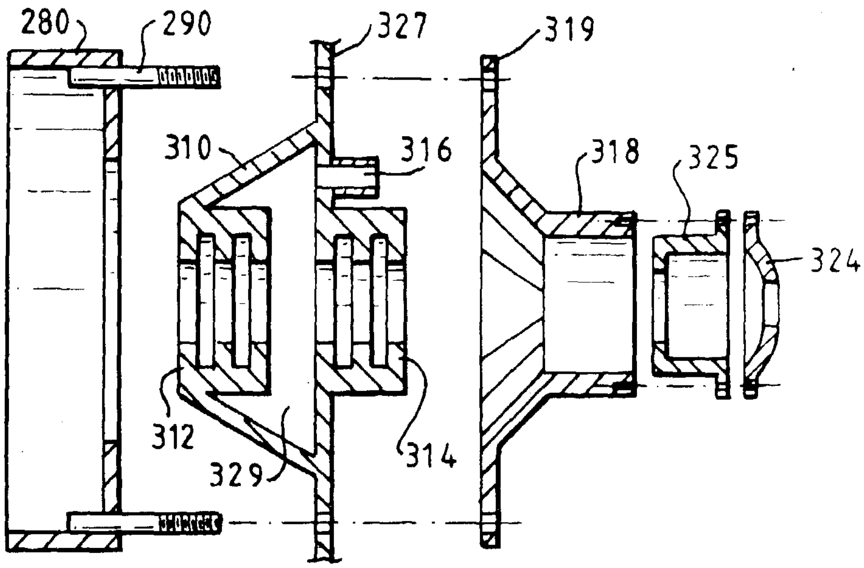
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FIG.9.

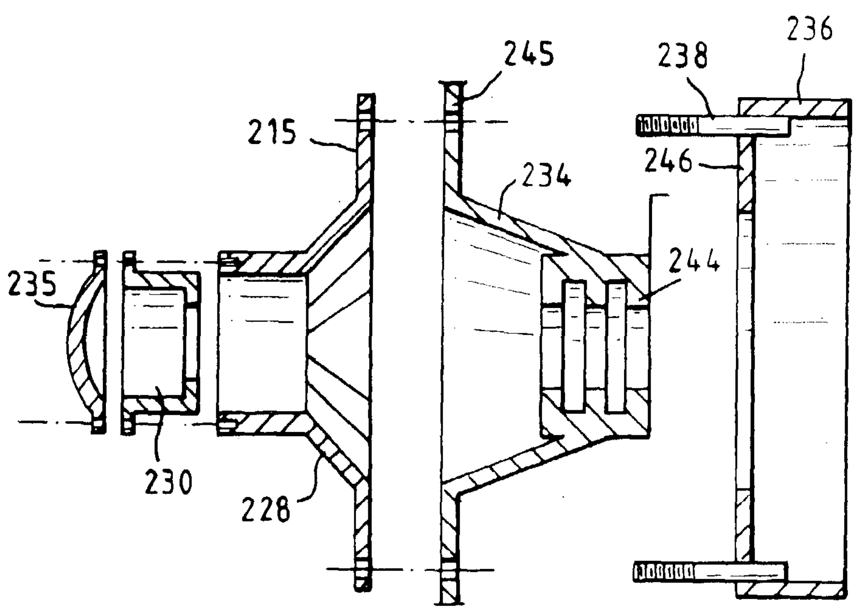
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FIG.10.

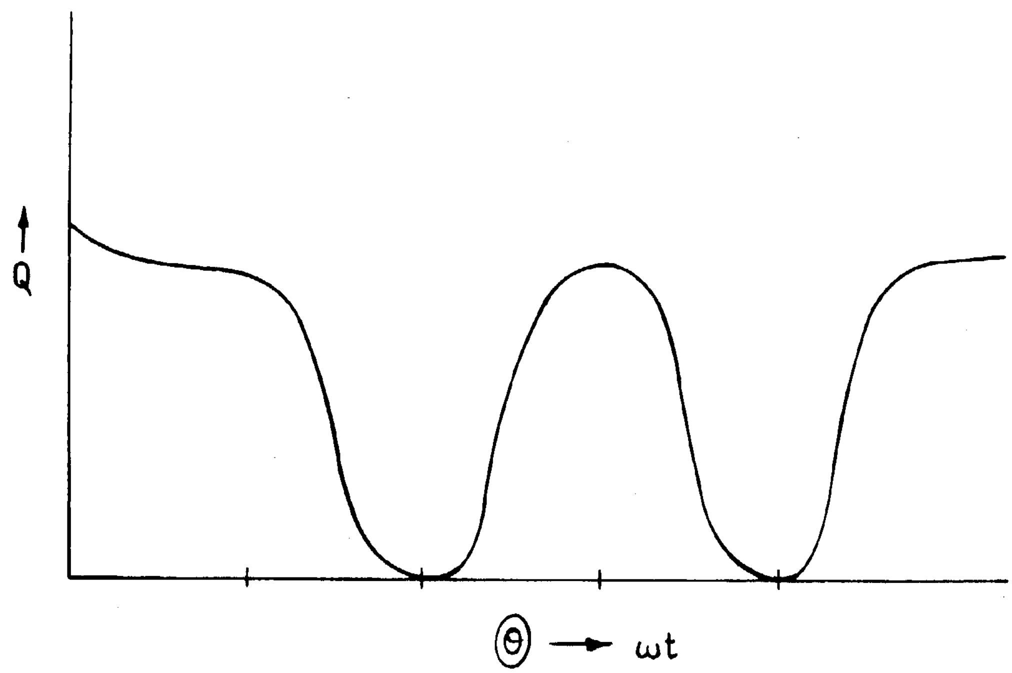

FIG.11.

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 92 30 6255

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	FR-A-1 287 425 (J. DEVOS)	1-7, 12-14, 17-24, 29,30	B01J19/18 B01J8/16 B01J19/10 B01F5/06 B01J10/00
A	* the whole document *	8,10,15, 25	
A	GB-A-865 127 (SOCIÉTÉ ANONYME FRANÇAISE POUR LA SÉPARATION, L'EMULSION ET LE MÉLANGE) * the whole document *	1-10, 12-15, 17-26, 29,30	
A	EP-A-0 291 820 (BAYER AG) * the whole document *	1-15, 17-26, 29,30	
A	FR-A-2 186 282 (W.R.JEWETT) * page 8, line 25 - page 9, line 31 * * figures 5,6 *	1,16,27	

TECHNICAL FIELDS SEARCHED (Int. Cl.5)

B01J
B01F

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	27 OCTOBER 1992	STEVNSBORG N.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

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